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The Influence of Environment on the Pigmentation of *Histrio histrio* (Linnaeus)

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(Plates I-III)

Introduction

The remarkable manner in which *Histrio histrio* (Linnaeus) disappears against a background of sargasso weed, with which it is so closely associated, has long been a matter of comment by both biologists and casual observers. This condition is facilitated by the form of the fish and its pigmentation. While, as noted by Breder (1946), *Histrio* cannot be easily counted among those fishes which closely imitate specific parts of plants in the manner defined by him, its general "ragged" appearance enables it to become extremely inconspicuous against an equivalent appearance which the weed produces, although the latter is considerably different in detail. This effect, so far as form is involved, is greatly enhanced by the fish's innumerable small "tabs" of skin, assisted in a measure by the exserted rays of the pectoral fins. With pattern and coloration these features account for all the physical elements in the near "invisibility" of *Histrio*. The coloration and pattern, almost entirely caused by the arrangement and colors of the chromatophores, are the features to which this study has been chiefly addressed, since it is this system which is basically responsible for the ability of these fishes to render themselves so well concealed.

The general difficulty encountered in finding *Histrio* against a background of sargasso weed has been mentioned in many, often popular, accounts of such matters. See for example, Braam Houckgeest (1774), Ives (1889), Vignon (1931), Gordon (1938) and Breder (1949). Casual observations in the field indicate that not only do these fishes show this general resemblance to *Sargassum* but that usually an individual matches the tan or yellowish color of the particular clump of weed on which it is found. While the range of coloration in these weeds is not great, there is sufficient variation to make such differences easily noticeable. Normally the fish are not found in other than living clumps of floating weed. Clumps which have been cast on the beach and refloated by a returning tide, after having been killed and dried in the interim, are much darker brown or sometimes nearly black. These have always been found to be devoid of *Histrio*. Thus these fishes are evidently not ordinarily called upon to respond other than to a limited range of color and pattern, as compared with the backgrounds against which most other color-matching fishes are exposed. For this reason, experiments were planned to determine the limits of the range of chromatic changes possible in *Histrio* as compared with the range of background which they ordinarily encounter, and in reference to the kinds and arrangements of the chromatophores with which they were provided.

The related various species of *Antennarius*, which are capable of much greater color and pattern changes, including brilliant reds, greens and yellows, are discussed comparatively with *Histrio*. Originally it had been planned to carry out an identical series of experiments on *Antennarius*, but, as is developed in the concluding remarks of this paper, it became unnecessary to do this for present purposes.

Most of the field observations mentioned herein were made while at The Lerner Marine Laboratory, on North Bimini in the Bahamas. All of the experimental studies were carried on in the laboratories of the Department of Fishes and Aquatic Biology of the American Museum of Natural History in New York. The living material established there was collected at Bimini, some by Dr. Louis Krumholz and some by Dr. Vladimir Walters. Dr. Walters also kindly supplied certain field data pertinent to these studies. The necessary sea water was obtained through the kindness of Mr. C. W. Coates, Director of the New York Aquarium, for which we are grateful. The description of the pigmentary systems involved are mostly paraphrased from notes prepared by Miss Priscilla Rasquin who was working at the time on the reproduction and embryology of these same fishes, reported in Rasquin (1958). The plastic films employed in some of the experiments were supplied by the Visking Corporation, New York City, through the kindness of its representative, Mr. Ronald Basso, for which we are most appreciative.

Experimental Backgrounds and Results

All of the following experiments were carried out in seven aquaria, each of which measured 2 ft. long by 1 ft. by 1 ft. These were supplied with the running sea water in a small circulating system set up especially for these experiments and described in detail by Breder (1957). The water used in the laboratory aquaria was obtained locally, most of it through the cooperation of the New York Aquarium at Coney Island. This was concentrated by evaporation to the approximate density of the water in which the fish were received, and held between 24° and 29° C., usually near 25°. The floors of these aquaria were covered about one-half inch deep in whitish calcareous sand from North Bimini. This served a practical maintenance purpose, as described by Breder (1957), and took on a reflected tint of the particular plastic shields employed. It was necessary to clean this sand periodically for both sanitary and chromatic reasons. The illumination used was entirely artificial and consisted of fluorescent tubes, of the so-called "warm white" type which are generally suitable for small aquaria in that they permit the satisfactory growth of green plants. This light source was directly overhead.

As *Histrio* customarily climbs about in sargasso weed, it was felt advisable to provide some sort of structure which would provide approximately similar support for such activity. Most of the larger marine algae, especially *Sargassum*, are difficult to maintain satisfactorily in small aquaria and in any case would interfere with the artificial chromatic arrangements. Therefore artificial supports of small glass rods 8½ in. high were built in the form of a tripod with extended arms of lesser-sized rods, as is shown in several of the plates. These were colorless in themselves and sanitary and at most reflected or refracted the color of the surrounding plastic shields. The spontaneous growth of adherent algae made it necessary to clean them periodically.

All the fishes were obtained from sargasso weed floating in the sea near Bimini. The smallest were shipped to New York by air express in the conventional plastic bags now in general use by aquarium dealers. Because of their well known voracious appetites, the fishes were kept separated by glass partitions in the tanks. They were fed daily with live *Lebistes reticulatus* Peters, *Astyanax mexicanus* (Filippi) and *Tilapia heudeloti* (Bleeker) of sizes suited to the individual *Histrio*. Most of the individuals were induced to accept cut up pieces of *Tilapia* and *Astyanax*.

Two sets of experiments were carried out, both in an effort to determine the extent of influence of the colors seen by the fishes on their pigmentation. In the first set, sheets of colored plastic were placed against the outside of the four glass walls of the aquaria. Matching strips of plastic were placed inside each corner of the aquaria to mask the blackish aquarium cement used to hold the glass sides in place. This plastic, a vinyl chloride-acetate copolymer to which pigment had been added, was first thoroughly tested, in each of the colors used, for possible biological effects and found to be entirely satisfactory. Since the colored plastic sheets, ⅛" stock, were somewhat translucent, transmitted light as well as that reflected from the inner surface of the sheets enhanced the chromatic values obtained.

In the second set of experiments the same aquaria were used, modified in the following way. The protective shields of colored plastic were removed and the tripods were wound with colored strips of polyethylene sheeting of 0.1 mm. or less in thickness. These, too, had been tested for biological effects and found to be satisfactory. A lesser variety of colors was employed for this series, because certain results in the first series had demonstrated some to be quite unnecessary. All other details were identical with those described for the first series except that corner strips were not necessary in the black aquaria, since the corners were already black. The polyethylene fringes for the glass tripods were made as follows. Plastic strips 1¾ in. wide were folded lengthwise. Repeated cuts were made in these at right angles to the fold by small scissors. The cuts were made from the edges which had been pressed together in folding so that the cuts nearly reached the line of fold. One end of such a fringed strip was then knotted to the lower end of the tripod and wrapped up it spirally. Others were attached to the cross rods. The finished appearances of these structures are shown in Plate I. It was found that the fishes made considerably more use of the tripods when so decorated and frequently nestled in this imitation sargasso weed, often disappearing as completely as they do when nestled in the natural plant.

The purpose in the design of these two series of experiments was to make a distinction, if any existed, between a general over-all coloration of the environment as compared with the details of the weed in which the fish nestle. In a state of nature, all that these fish normally view is the more or less checkered sargasso weed and its other closely matching attendant organisms in the bluish void of the lateral viewing of the open ocean. This is only interrupted by the comparatively infrequent appearance of some passing larger fish or smaller food object. In the first case it was the general over-all water color that was changed by the slightly translucent plastic shields, while in the second case the colors of the "weed" itself were modified.

A schedule of the period of days in which the various individuals occupied the different aquaria is given in Table 1, covering both the first and second series. In all, 42 individuals were used in these experiments, 19 of which may be considered as controls, that is, fishes kept in clear glass aquaria and not exposed to specific colors as previously described. The 23 remaining fishes were exposed for varying times and under other differing conditions to these especially prepared colors. In addition to black and white, four colors were employed for this purpose: red, yellow, green and blue. There was one aquarium so shielded by each of the six plastic shields above named. No attempt to define these colors in terms of wave length has been made, since this refinement appeared to be quite unnecessary for the purposes of the project, and as it was well known in advance that these fishes could match a fair range of sargasso

TABLE 1. EXPOSURE OF *Histrio* TO VARIOUS COLORS, IN DAYS

Fish number	Aquaria						
	Clear	White	Yellow	Red	Green	Blue	Black
1	54						◄85
2	19➤	83					
3						20	
4						66	
5						13	
6				183			
7				14			
8				178			
9			48		80➤		48➤yellow
10			54		80➤		48➤yellow
11			42		80➤		48➤yellow
12			128➤blue		25	◄29	
13			127				
15	3➤black				101		◄77
16	2➤	18					
19	5➤	118					
21	5➤					62	
23	5➤		147➤32f				
26	5➤						71➤82f
32	3➤					48➤114f	
35	3➤						54➤82f
36	3➤	101					
37	3➤		55➤117f				

NOTE. Arrows indicate direction of change to another color, named where necessary.

"f" indicates tripod has fringe of color indicated.

In addition to the above 23 numbered individuals there were 19 controls as follows: 14, 17, 18, 20, 22, 24, 25, 27-31, 33, 34, 38-42.

There is no indication of number of companions, if any, nor of shifts without color change, incident to operations in this tabulation.

The fishes arrived and were placed in the aquaria indicated according to the following tabulation.

Nos. 1 to 3, 3/22/56	Nos. 29 to 37, 12/25/56
Nos. 4 to 16, 5/1/56	Nos. 40 to 41, 5/27/57
Nos. 17 to 28, 12/6/56	No. 42, 6/23/57

weed hues. The fringed tripods were prepared in yellow, blue, black and clear, while red developed spontaneously by the overgrowth of a red alga on a tripod fringed with clear plastic. Five fish were used in connection with these decorated tripods, most of which had been previously exposed to plastic shields of the same color. The days spent under each condition and the sequence of change are given in Table 1. Other details are given in the text where they are pertinent. The missing numbers of individual fishes refer to the controls, which were maintained in ordinary aquaria up to 193 days.

The details of the experiments indicated in summary in Tables 1 and 2 are as follows, arranged by color and followed by those concerned with changed colors.

Black.—The four fish exposed to black in the manner described all gave clear and definite reactions. They all were very dark by the time they had been continuously exposed for 2 to 3 weeks. The resulting darkening for Fish No. 1 and Fish No. 26 is shown in Plate I after exposures of 30 and 103 days respectively.

Yellow.—The ten fish exposed to yellow all showed an appropriate change in a more yellow over-all appearance and a lessening of pattern detail. This was, however, not nearly as pronounced as in the case of the black backgrounds, partly, at least, because the yellow backgrounds called for less of a change from the initial condition of the fishes than in the former. In Plate I, Fish No. 13 and Fish No. 37 are shown with plain and fringed tripods. These illustrations were made after the fish had been exposed for 38 and 85 days respectively.

Red.—The differences between the unexposed fish and those exposed to red were slight and somewhat uncertain and could not be detected in a black-and-white photograph. Consequently no illustrations are given covering these three fishes.

Green.—While there was no evident response to green, three fish which were simultaneously exposed to green for 79 days are shown in Plate II. These three fish, Nos. 9, 10 and 11, all showed different basic patterns when introduced into this single partitioned aquarium and maintained them throughout the study. The possible significance of these patterns differs. Two other fish, Nos. 12 and 15, the latter having first been exposed to black, were also exposed to green, making a series of five fish. All performed in an essentially similar manner, including the black fish, No. 15, which, while lightening slightly, agreed with the rest in showing no direct response to green. The lightening was very limited, as would be expected because of the size and age of the fish which had long passed its peak of maximum response to background colors.

Table 2. Sizes of Various Individual *Histrio* at Particular Times

Fish number	Size on arrival	Size when photographed	Date when photographed	Figure number
1			4/20/56	1
26	18	65	3/19/57	2
13			6/7/56	3
37	25	77	3/19/57	4
9			7/18/56	5
10			7/18/56	5
11			7/18/56	5
2			5/2/56	6
14			5/2/56	7
28	15	48	1/4/57	8
29	43	65	2/26/57	10

Note. All measurements are given as millimeters in total length. Dates of measurements are approximate.

Blue.—Six fish, Nos. 3, 4, 5, 12, 21 and 32, were exposed to blue and showed absolutely no tendency to approach that color. It seemed that the fishes did not thrive nearly as well in the blue aquarium as in the others, several early deaths appearing which it was thought might have been in some obscure fashion connected with the color involved.

White.—The four fish exposed to white, Nos. 2, 16, 19 and 36, all showed either a definite lightening or an evident great increase in brilliance in the white spots made up of crowded leucophores, or both. There was no close approach, however, to white in any real sense. Indeed, this would have been very difficult, for even if all the chromatophores could be reduced, it would require a tremendous overgrowth of leucophores to mask the underlying tissue colors. Plate II, fig. 6, shows Fish No. 2.

Clear.—In addition to the two fish, Nos. 1 and 2, there were 19 "control" fish not listed in Table 1 which were kept in similar aquaria. The long series of fish kept in clear aquaria from 2 to 5 days were held there merely preparatory to transfer and the periods were too short to have any bearing on these experiments. All these fish changed less than those which were exposed to colored backgrounds, which gives support to the significance of the colors to the chromatic changes observed on the experimental fishes. Plate II, fig. 7, and Plate III, fig. 8, show Fish No. 14 as kept in an ordinary clear glass aquarium and Fish No. 28 in association with clear fringe.

The Pigmentary System and Its Limitations

The following descriptions cover the kinds and distribution of the chromatophores and related structures as viewed on the living fishes through stereoscopic dissecting microscopes. These features cover the mechanism by which color and pattern changes are effected in *Histrio* and the cellular types present give an effective measure of the limitations present in their particular chromatophore system.

The pigment cells present are of three kinds only, melanophores, xanthophores and leucophores. The xanthophores are deep yellow, nearly approaching orange. The leucophores show no iridescence, all being of the milk white type.

The typical condition found in *Histrio,* with little variation, is as follows. The most deeply pigmented patches in the dermal pattern seem to be composed entirely of melanophores and xanthophores. If there are any leucophores present in these areas they are evidently completely obscured by the overlaying of the more deeply colored cells. Both the melanophores and xanthophores are small in size, but exceedingly numerous and very closely crowded together in the darker areas of the skin. The sharpness of the pattern shown by *Histrio* is accentuated by the abrupt ending of the more heavily pigmented areas, which have very sharp lines of demarcation between them and the lighter areas of the pattern. In the latter there are few, if any, straggling melanophores or xanthophores. Some leucophores are present in these clear areas, but they are sparse, to the point where the vascularization of the dermis can be easily distinguished. The coloration of these lighter areas is based to a large extent on the nature of the underlying tissues, including principally a reddish suffusion of the blood, a pale yellowish from fat and a whitish tint from the muscles. The opaque white spots are composed entirely of tightly packed leucophores. All these features are displayed in the post dorsal area of skin shown in Plate III, fig. 9. Although this picture was taken of a freshly formalin-fixed fish, it is still typical of the living animal.

In fishes which have become nearly entirely black, as Fish Nos. 1 and 26 of Plate I, figs. 1 and 2, there has clearly been an enormous increase in the number of melanophores. The greatly reduced clear areas contain straggling cells of both melanophores and xanthophores and the line of demarcation between the originally dark and clear areas is not nearly as sharp as in the lighter-colored fishes. Some of the remaining white spots contain xanthophores as well as leucophores while others remain as colonies of pure leucophores.

Fishes which have become more yellow, as Fish No. 37 of Plate I, fig. 4, show more clear spaces than the controls. Straggling xanthophores are found in these spaces but no melanophores. None of either were found in the white spots. The xanthophores are of a particularly brilliant orange hue.

It seemed that fishes which had been kept in a red aquarium just barely suggested a slightly reddish hue, but this was too indefinite to be rigidly established. Fish No. 8, which had been kept in a red aquarium for 178 days, was such a case and its faint but seemingly reddish hue was evidently caused by its deeply colored xanthophores, combined with many black melanophores. The particular adjustment between them may indeed have been as far as the fish was able to go in the direction of matching a red background with its rather limited chromatophore system. The yellow fish above mentioned has its intense yellow caused, not by paler xanthophores, but by more of them and fewer melanophores than Fish No. 8. Xanthophores on the black fish, No. 1, are mostly covered by the very numerous melanophores, but what few were visible were definitely paler than on the other fishes.

It should be noted in these connections that the presence of the white patches formed of massed leucophores sometimes gives a false sense of color, as they take on the hue of their surroundings, making a fish on yellow, for instance, appear to be yellower than it actually is. This effect helps enhance background matching in a purely passive way. Because of this condition, caution was taken in the observations to make necessary allowances, often by viewing the fishes against a neutral gray background instead of the background of the colored containers.

While it is clear that the colors can and do change considerably in reference to the background, differences in pattern, which are evidenced in the smallest individuals obtained, do not vary to any noticeable extent except as certain markings may be obliterated by masking, as in the very dark color phases. The basic design on each fish seems to be fixed for life. Whether this pattern is largely genetic or largely fixed at a very early stage, at sizes as yet not obtainable, is still unknown.

As in all fishes showing marked ability to change their coloration, there are two elements in the response which must be distinguished in order to proceed with a satisfactory discussion. The rapid changes, sometimes almost instantaneous, are all due to prompt reactions involving the dispersal or concentration of the chromatophore pigment granules. These, while striking in their speed and extent, are not as profound as those which take a longer time to appear, covering periods of weeks or months. The first kind are under the immediate control of the nervous and hormonal systems and the reactions are at speeds consistent with those systems. The slower type is based on the development of more color cells and thus involves a true morphological modification. The color changes here under consideration all refer to the second or morphological changes, as many days are involved in their development. *Histrio* is capable of making sudden changes in coloration but it is not, as a species, especially marked in this direction. When sudden change does occur, it is more apt to be associated with some influence other than background—as for example during breeding periods when radical changes in coloration sometimes appear for short periods. These changes are sometimes striking to the eye but are not nearly as fundamental as the great increase in the numbers of melanophores which an individual will develop against a black background.

Discussion

It is shown in the preceding sections that *Histrio* responds rather slowly, but very definitely, to colors in its surroundings. These responses are evidently rather severely restricted to the colors found in sargasso weed, or perhaps with little extensions of them into blacks and yellows. This situation is evidently a matter of the physical limitations of the chromatophore system. Whether there is also a behavioral limitation involved, of course, cannot be verified by direct experimentation. Since, however, the not distantly related *Antennarius* can, in various of its species, show a much greater range of chromatic adjustment and necessarily has a larger number of types of chromatophores, it would seem that *Histrio,* if not so restricted by its chromatophore system, should be able to do as well. This view is supported by the excellent matching effect which *Histrio* attains with its limited chromatic abilities within the environment with which it is normally associated.

Nearly all of the individuals of *Histrio* encountered in the field are found in close association with *Sargassum,* both from personal observation and the reports of collectors and the literature. The initial observation, which prompted the undertaking of the experiments herein described, was made in an aquarium in the Lerner Marine Laboratory. This tank, which had a light sand bottom, had been painted black on its back and two ends. Into it had been inadvertently dropped a very small *Histrio* incident to some entirely unrelated operations, on November 15, 1954. The only other contents of this 3 × 1½ × 1½ foot aquarium were the light sand bottom and a dozen or so small *Sardinella.* There was no *Sargassum* or other floating weed. The small *Histrio* usually was to be seen wedged in a corner near the surface. This fish, originally of the usual coloration and pattern, by December 3 was a perfect match for the dead black background against which it had been living. Not only was the black background matched perfectly but there appeared on the sides of the fish a few small milk-white spots, which were the size and shape of a scattering of equally white volunteer calcareous growths on the black glass. The resemblance of the white spots to the growths may have been purely accidental, as these fishes normally display some milk-white spots which usually go unnoticed in their otherwise mottled pattern. However, as was noticed in the later experiments, the very smallest fishes made the most striking adjustments to background, whereas the larger in no case did nearly so well. It is possible that the size and shape of the white spots on the fish above described were pattern adjustments, beyond the capabilities of the considerably larger fishes studied later. It may be that much greater adjustment to both colors and pattern of background is a capability of these fishes at sizes well below those ordinarily obtainable. It would certainly be desirable to work from the transparent planktonic larvae just before they settle in the *Sargassum* in any attempt to analyze the potentialities of smaller fish. Such material is not obtainable by any presently known means.

Aside from this fish that turned black in an aquarium, there appears to be no previous record of black *Histrio.* Three years later the following observations were made near the laboratory. These constitute the only known occurrences of black *Histrio* in a state of nature and have a very distinct bearing on the present experiments. Dr. Vladimir Walters, working on other matters, collected three such black *Histrio* on March 30, 1957, in one of the passages through the mangrove stands along the south side of South Bimini. The specimens were subsequently lost in shipment, but he described them as closely resembling the most thoroughly black fishes developed in the laboratory. Although many persons working out of the Lerner Marine Laboratory had collected in this same place and in many others basically similar to it, there have been no other reports of *Histrio* in these places whatever. In the present case, rotenone was used in collecting, which may be responsible for finding them at all. It is to be noted that especially heavy weather the preceding month had brought quantities of sargasso weed closer to the mangrove stands than usual.

The presumed fate of these black *Histrio*, stranded in a mangrove swamp and living against a very black background, would seem to be obvious enough even if the precise reasons are not clear. In the light of aquarium observations, it would seem that such fish should be able to manage well enough, by taking on the habits of an *Antennarius*, which is something they may approximate in an aquarium without artificial weed. That they are not very successful in mangrove swamps is evidenced by their normal absence from such places. At least, it would appear that this is not based on any inability to match the mangrove background. It could be that there is some element in the mangrove association with which they are unable to cope. This could conceivably be the frequent abundance of large callinectids, so often found in such associations. If actual destruction of the fishes did not take place by some such means, it is conceivable that the fish might escape back to their normal environment, a seemingly unlikely event. The general reluctance of fishes to leave a background to which they are chromatically adjusted would have to be over-ridden at some stage in any attempt to work out of a mangrove stand. There are no available step-by-step environmental niches through which they could make an easy transition from mangrove-black to sargasso-mottled, especially in view of the sluggishness of their chromatic adjustments.

The ability of *Histrio* to assume the behavior usually associated with *Antennarius*, as above noted, was nicely demonstrated by one that was placed in an aquarium where the sole fitting was a small shell, *Melongena*. This it associated with to the extent of spending much time huddled against it or even within the mouth of the shell. A typical posture of this fish is shown in Plate III, fig. 10. Not only were the postures reminiscent of *Antennarius* but often the movements of the pectorals and the creeping about on the aquarium floor resembled the movements of that genus rather than *Histrio*. As might be expected, the darker markings of this fish took on a brown hue very close to that of the brown markings around the lip of the shell.

The formal experiments agree well with the field observations and of course show that *Histrio* is well able to make chromatic adjustments involving mottled patterns from black through various brown and yellowish tans to a fair yellow. Also because of the islands of leucophores, they are able to take on the appearance of overlaid whitish patches, not unlike various of the sessile epizootics on *Sargassum*. Actually this range goes little further than covering the range of possibilities of this somewhat variable weed but to which can be added any dominantly black environment such as a mangrove swamp. Other backgrounds do not yield such striking results. Green and blue, which are the backgrounds which one would expect to call for the presence of iridophores and combinations of chromatophores into chromatosomes, yielded no recognizable response. Red, which might be expected to call for erythrophores, which too, are absent, yielded only questionable response of a slight sort. Actually what appeared to be a slight response was caused by a particular mixture of melanophores and xanthophores. This indeed may have been a tendency to produce a red color but one impossible of attaining any real success with the pigments present. White and clear, the latter in the form of plastic fringes, caused only a general lightening of the fish, *i. e.* a reduction in the number of melanophores and xanthophores with perhaps some increase in the number of leucophores. While this results in a better matching than red, green or blue, it is not in the same class at all with the effects induced by black or yellow.

It is interesting in the above connections to consider the three fish shown in Plate II, fig. 5. Not only do they show marked differences in pattern but also at least equally marked differences in amounts of pigmentation. As may be seen in the photograph, the fish at the left showed a comparatively heavily pigmented pattern of broad blotches while the central fish showed conspicuously less pigmentation and the right hand fish showed pigmentation comparable to that of the left hand fish but in a much finer pattern. It would seem almost that these fishes either reacted in no way at all to the green color and retained whatever tendency they had been impressed with before capture, or that they each reacted in a distinctly different manner to a common background which was neither very light nor very dark. It is evident in any case that this color green, to which so many fishes respond by matching, is evidently completely out of the chromatic reactivity of these fishes which respond so markedly to the yellow browns of the weeds which they normally inhabit.

In these studies, several fish showed aberrations in their chromatic behavior that are not easily explained, the details of which are given in the preceding section. These would all appear to be due to some derangement in the complex system responsible for fishes responding with their pigmentary effectors from colors thrown on the retina, as the mediating receptor. This is too poorly understood and too complex a matter to be discussed in present connections, except to suggest that these sometime reverse responses may be at the basis of the cause which impels a fish to change from a background-matching habit to one of background-opposing. Influences bearing on these two diametrically opposed reactions to background are further discussed by Breder & Rasquin (1955) and Breder (1955) in reference to other fishes.

While it has been impossible to obtain sufficient material of *Antennarius* to perform a set of parallel experiments, observations on these fishes show them to have chromatic possibilities far exceeding that of *Histrio*. Barbour (1942) and Schultz (1957) indicated the highly variable coloration and pattern differences seen in these fishes. Individuals of *Antennarius multiocellatus* (Cuvier & Valenciennes) have been seen to vary through shades of red, vivid green, brilliant yellows, black and gray or brown mottlings. These are believed to represent only a few of the chromatically possible arrangements of which this particular species is capable. Not only does this species, at least, show such background-matching proclivities, but may alternate it with background-opposing coloration. The behavior of one individual in regard to this latter feature is discussed by Breder (1949). It is to be noted in reference to the above that this behavior in *Antennarius* was found to occur in environments where a variety of other fishes also show the background-opposing response.

An examination by Dr. Walters, of the pigmentary system of a freshly fixed specimen of *Antennarius ocellatus* (Bloch & Schneider) from the Dry Tortugas, showed the following conditions. This fish, still pinkish in coloration, possessed melanophores, erythrophores and leucophores, but no xanthophores or iridophores. A full study of the presences and absences of the various chromatophore types should be interesting and illuminating.

These considerations lead to the idea that *Histrio* certainly descended from some form less restricted as to habitat, that it had an ancestor with greater chromatic range, perhaps similar to that found in *Antennarius*, and that therefore the condition presently found in *Histrio* is to be considered one of loss of certain pigmentary elements. Schultz (1957) considers *Histrio* and *Antennarius* as derived separately from what he calls "antennariid stock" rather than as having any closer relationship. That these retained pigmentary elements permit the fish little ability to change color outside the range of those found in *Sargassum* certainly suggests a long-time assotion between the two. Also in reference to the *Histrio* in the mangrove swamp, it further suggests that such occurrences are probably very rare and are likely terminal wastage rather than some obscure but normal alternative open to these fishes in the ordinary run of their lives.

Summary

1. *Histrio* has little ability to match backgrounds outside of the range of colors displayed by *Sargassum*.
2. Black is well matched and yellow not quite so well while with other colors attempts to match are absent or negligible.
3. The only chromatophores present in the integument of *Histrio* are melanophores, xanthophores and leucophores, a condition which in itself is perhaps sufficient to explain the restricted chromatic ability of these fishes.
4. The related *Antennarius* is capable of much greater chromatic adjustment because of the presence of other types of chromatophores and is found to inhabit places which expose it to backgrounds which show a correspondingly greater range of colors.
5. It is inferred that *Histrio* descended from a chromatically more competent ancestor and the present chromatophore complement is one of loss and indicates a long association with *Sargassum*, in which these present elements have sufficed.

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EXPLANATION OF THE PLATES

Note. In all photographs of living *Histrio* a temporary background of a neutral gray card was substituted for colored plastic shields, except in Plate 2, fig. 5, in which the green plastic shield was left in place. In all but the excepted case this was necessary to make these fish sufficiently visible for photography. It is to be especially noted that in reduction to monochrome the pictures lose much of the effective resemblance these fishes exhibit toward their colored backgrounds.

Plate I

Histrio after exposure to black and to yellow

Fig. 1. Fish No. 1 after 30 days behind black shields.

Fig. 2. Fish No. 26 after 82 days with black-fringed tripod.

Fig. 3. Fish No. 13 after 38 days behind yellow shields.

Fig. 4. Fish No. 37 after 85 days with yellow-fringed tripod.

Plate II

Histrio; various exposures

Fig. 5. Fishes Nos. 9, 10 and 11 after 79 days behind green shields, showing basic pattern differences.

Fig. 6. Fish No. 2 after 23 days behind white shields.

Fig. 7. Fish No. 14 the day after arrival, for comparison with the experimental fishes.

Plate III

Histrio; chromatic and behavior details

Fig. 8. Fish No. 28 after 85 days with clear-fringed tripod.

Fig. 9. Magnified area at dorsal base on the right side of Fish No. 12 showing the main features of chromatophore cell types.

Fig. 10. Fish No. 29 after 64 days' association with a shell.